Blood flow in ductus venosus in early uncomplicated pregnancy

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Abstract

The ductus venosus is the very important part of fetal venous circulation. It plays a central role in return of venous blood from the placenta. This unique shunt carries well-oxygenated blood from the umbilical vein through the inferior atrial inlet on its way across the foramen ovale. Using Doppler ultrasound, it is possible to assess the blood flow in fetal vessels including ductus venosus. It is observed, in animal and human studies, that the typical waveform for blood flow in ductus venosus in early pregnancy can be different depending on numerous conditions e.g. fetal karyotype. This study is performed to assess the physiologic parameters of blood flow in ductus venosus in uncomplicated early pregnancy. Material and Methods: 404 women were examined between 11+0 and 13+6 weeks (+ days) of gestation by ultrasound. Fetal crown-rump length (CRL) was measured to assess the gestational age. The assessment of risk of fetal abnormalities was based on nuchal translucency (NT) measurement. The ductus venosus blood flow with color and spectral Doppler was obtained in all patients. The following features were assessed: pulsatility index (PI), and direction of flow (positive/negative) during atrial contraction (wave A). All cases were followed up to 22 weeks of gestation when the control scan was performed. Results and conclusions: 30 cases were excluded from the uncomplicated group due to: high risk of fetal abnormalities, fetal loss, confirmed fetal abnormalities and utero-placental pathology. 374 women were considered as uncomplicated pregnancy. In both uncomplicated and complicated groups the mean values for pulsatility index (PI) were established. The mean PI value in uncomplicated pregnancies was: 0.91 (SD ± 0.32). No significant differences between groups were noticed. In 370 cases of uncomplicated pregnancy the A wave direction was positive but in 1.1% of cases the reverse flow in atrial contraction was observed.

ORIGINAL ARTICLE

INTRODUCTION

The ductus venosus is a part of human fetal circulation. It is a trumpet-like, small vein with a narrow entrance that connects the umbilical sinus to the hepatic veins and inferior vena cava. With an advancing gestation the ductus venosus shows a growth in length maintaining its shape. Highly oxygenated blood from the placenta flows through the ductus venosus directly towards the foramen ovale and the left atrium of the fetal heart. It has been proposed that shunting of umbilical blood through the ductus venosus is actively regulated at the level of the ductus venosus inlet, and that the degree of shunting varies under different physiological and pathological conditions [1,2].

Introduction of Doppler velocimetry of the ductus venosus in human fetal circulation has opened a new era in the parental fetal assessment [2]. It is proven that Doppler studies are of great importance in continuous monitoring of fetuses with intrauterine growth restriction due to placental insufficiency. Recent reports have raised interest in ductus venosus Doppler studies at 10–14 week of gestation, demonstrating an association between normal flow patterns and fetal chromosomal abnormalities, congenital heart defects or adverse pregnancy outcome in high risk pregnancies and in the general population [1]. The flow velocity waveform of the ductus venosus displays a continuous forward flow throughout the cardiac cycle. The typical biphasic waveform consists of two surges of velocity peaks, the first corresponding to ventricular systole (S wave) and the second to ventricular diastole (D wave). These are followed by a reduction in velocity during the atrial systole (A wave) [3] (Figure 1). In several studies absent or reversed flow during atrial contraction was correlated with abnormal pregnancy outcomes – e.g. fetal chromosomal abnormalities and/or congenital heart defects [4,5] (Figure 2). This study is performed to assess the physiologic parameters of blood flow in ductus venosus in uncomplicated early pregnancy in Polish non-selected population.

MATERIAL AND METHODS

404 women in uncomplicated pregnancy were examined between 11+0 and 13+6 weeks (+days) of gestation by ultrasound. Ultrasound examinations were performed transabdominally with a GE Voluson 730 Expert equipped with 5–7.5 MHz convex probe. Fetal crown-rump length (CRL) was measured to assess the gestational age and the careful search for fetal abnormalities was performed. The assessment of risk of fetal abnormalities was based on nuchal translucency (NT) measurement. The patient was considered as high-risk when the estimated risk of fetal abnormalities was 1:300 or higher. In each fetus, a right ventral mid-sagittal plane was obtained. The ductus venosus was identified by color Doppler imaging. After the flow velocity waveform of the ductus venosus was obtained, the following features were assessed: pulsatility index (PI), direction of flow (positive/negative) during atrial contraction (wave A). The pulsatility index (PI) is defined by equation:

$$PI = S - D/A$$

where S is the maximum peak systolic frequency, D is end-diastolic, and A is the mean Doppler shift frequency during cardiac cycle.

All cases were followed up to 22 weeks of gestation when the control scan was performed. Patient was excluded from the study if any fetal abnormalities, fetal demise or obstetrical complications were observed.

RESULTS

Four hundred and four consecutive pregnant women between 11 weeks +0 days and 13 weeks +6 days of gestation were included in the study. The mean maternal age was 31.22 (range 14–43) years, and the mean gestational age was 12 weeks + 6 days (range 11+0 to 13+6). The low risk group consisted of 374 patients. Thirty patients of high risk of fetal abnormalities were excluded from the further analysis. The biometric data and Doppler measurements are summarized in Table 1. Of the 374 "low

Table 1. Biometric measurements and ductus venosus PI in the high- and low-risk subgropus.

	Low risk n=374; mean (SD)	**High risk** n=30; mean (SD)	*** p-value**	**Difference of means**	**95% CI for difference of means**
Maternal age (years)	38.5 (3.3)	36.7 (6.3)	0.18	1.83	0.90 to 4.57
CRL (mm)	64.9 (11.6)	63.6 (11.2)	0.68	1.32	–5.34 to 7.9
NT (mm)	1.5 (0.42)	2.9 (1.9)	0.0003	–1.40	–2.11 to –0.7
PI	0.91 (0.32)	1.13 (0.58)	0.1	–0.21	–0.48 to 0.047

CRL – crown-rump length; NT – nuchal translucency; PI – pulsatility index
* - t-test for comparison between subgroups

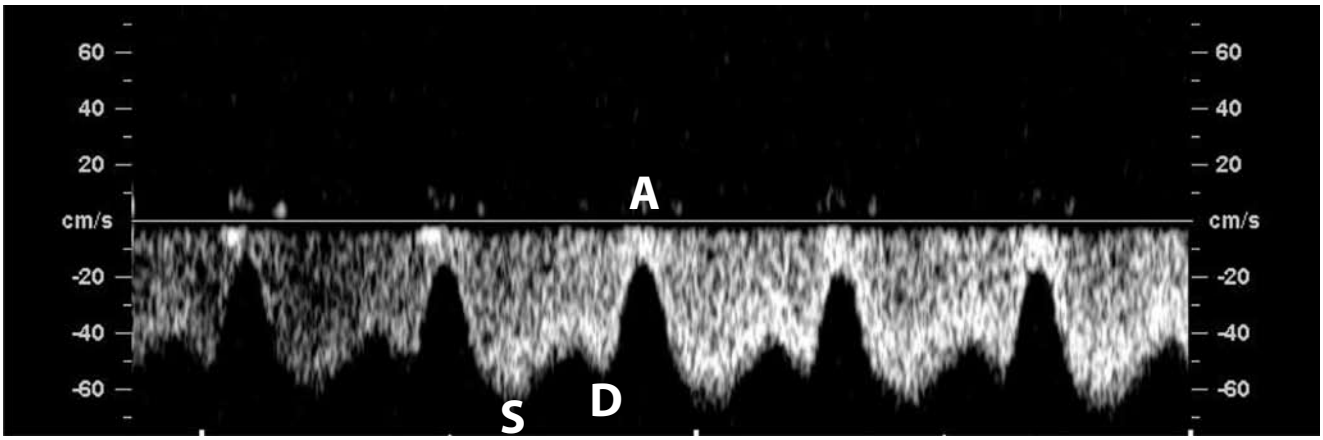

Figure 1. Normal ductus venosus flow pattern. (S - ventricular systole, D - ventricular diastole, A - atrial systole)

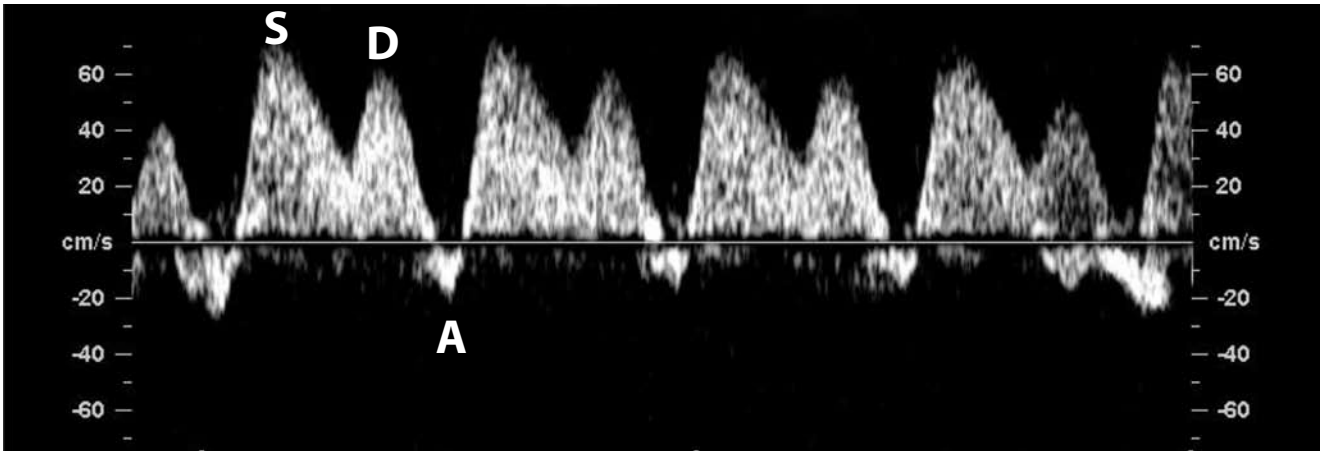

Figure 2. Abnormal ductus venosus flow pattern with reverse flow during atrial contraction. (S - ventricular systole, D - ventricular diastole, A - atrial systole).

risk" fetuses, 370 showed normal flow pattern in ductus venosus with positive flow during atrial contraction. The prevalence of absent or reversed flow during atrial contraction in this group is: 1.1%. In 7 cases (23.3%) of complicated pregnancy the reverse flow in atrial contraction was observed. The reference ranges calculated in the 374 fetuses with a normal flow pattern are shown in Figure 3. The equation for the 50th centile is: $y = -0.0018x+1.0145$. The PI values had no statistically significant correlation with CRL values (Pearson's $r = -0.06$; $p=0.22$).

DISCUSSION

Recently, the role of ductus venosus Doppler velocimetry in the assessment of early pregnancy has been investigated in several studies [4,6,7]. The preliminary results showed its diagnostic potential comparable with nuchal translucency measurement in screening for chromosomal abnormalities. Several studies focused on the association of abnormal ductus venosus flow patterns with congenital heart defects [4,6,7]. We aimed to determine reference values for pulsatility index measured in ductus venosus and to assess the prevalence of abnormal follow pattern (defined as absent or reverse flow during atrial contraction) in low-risk, uncomplicated pregnancies.

Pulsatility index (PI) is showed to be the parameter with a good intraobserver measurement's repeatability [8]. Prefumo *et al*. assessed the reference values in ductus venosus velocimetry in 198 patients with normal early pregnancies. PI showed a decreasing trend with advancing gestation, which did not reach statistical significance during the narrow gestational interval studied [9]. Similar observations were reported by Bahlmann *et al*. in 2000 [10]. Our data presented in this issue are in accordance with the literature.

The prevalence of abnormal flow pattern in ductus venosus in normal fetuses in our data is 1.1%. Several studies confirm the association of absent or reverse flow patterns with cardiac defects, chromosomal abnormalities and adverse outcome of the pregnancy [7,9]. But, according to Hecher, the results of all these studies cannot be applied to a low-risk population [11]. We don't know the true prevalence of ductus venosus waveforms with absent or reversed flow during atrial contraction in normal pregnancies and this parameter cannot yet be used as the screening test. Our data indicate that such ab-

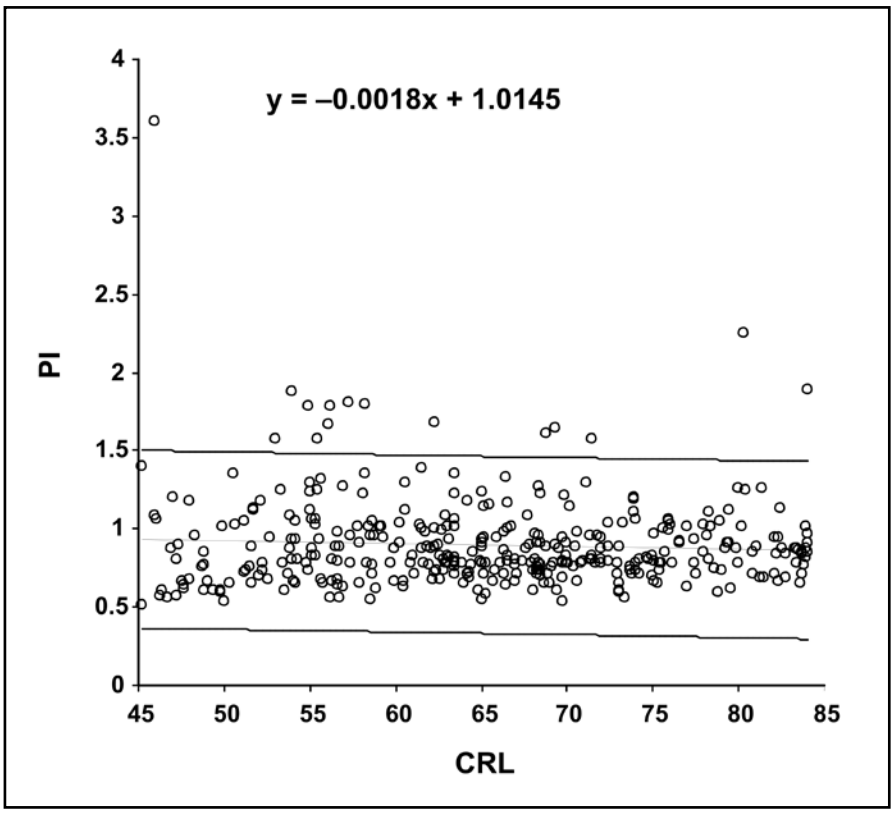

Figure 3. Ductus venosus pulsatility index measurements according to crown-rump-length in 374 fetuses presented with 5th, 50th, and 95th centiles.

normal patterns are not rare in normal fetuses which is in accordance with the literature. This may be caused by the technical difficulties while obtaining the ductus venosus waveform. In 11+0 and 13+6 weeks (+days) of gestation the length of ductus venosus is about 2–3 mm [11]. The reference point of obtaining waveforms is very close to the neighboring pericardial and hepatic vessels and their signals may cause the contamination of ductal waveform. This may lead to misjudgment of positive/negative flow during atrial contractions in ductus venosus [11].

CONCLUSIONS

1. Reference values of PI measured in ductus venosus in early uncomplicated pregnancy in Polish population are in accordance with the literature.
2. The prevalence of abnormal flow patterns in low-risk population and its diagnostic values need further studies.

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